

NUCLEAR FUSION RATE OF THE MUONIC T_3 MOLECULE

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The ground state binding energy, size, and effective nuclear charge of the muonic T_3 molecule are calculated using Born-Oppenheimer adiabatic approximation [1,2]. The system possesses two minimum positions. A symmetric planar vibrational model between two minima is assumed and the approximated potential are calculated in this region. Moreover, nuclear fusion rate calculations of the short-life molecule is carried out due to the overlap integral of the resonance nuclear compound nucleus and the molecular wave functions. The molecular wave function, Ψ_{mol} , representing the motion of ${}^6Li^*$ and t nuclei under the influence of an effective attractive potential and strong Coulomb repulsion, in the unit of $\hbar = e^2 = c = 1$, is written using phenomenological idea so that at large distances the wave function, which describes the size of the molecule, decreases exponentially:

$$\Psi_{mol}(r) = N_{mol} \frac{F_0(\eta, r)}{r} e^{-kr} \quad (1)$$

where $k = 2m_t \mathcal{E}_l$ is the wave vector, and N_{mol} is the normalization factor calculated due to the molecular size, and $F_0(\eta, r)$ is the regular Coulomb solution which its parameters are defined in the full text. The probability of nuclear fusion, $\mathcal{W} = 2\pi(|\mathcal{E}_l - E_{th}|) < \Psi_{mol} | \Psi_{res} >^2$, is obtained from the overlap between the molecular and resonance wave functions. The resonance state $\Psi_{res}(r)$ is simply chosen as an outgoing Coulomb s-wave:

$$\Psi_{res}(r) = N_{res} \frac{e^{i\eta \ln qr}}{r} \quad (2)$$

where $\eta = Z_{eff} \frac{q}{k}$ being the Sommerfeld parameter (here the fine structure constant α is equal to 1 in a.u.), and $q = \sqrt{2m_t |\mathcal{E}_l - E_{th}|}$, respectively. \mathcal{E}_l is called the relative outgoing energy which is computed, and E_{th} is the threshold energy. Also N_{res} is the normalization factor in the nuclear volume. To avoid to more complexity, we ignored the Ω dependency of the wave function. According to the above assumptions, the transition amplitude (after integrating analytically over r), is given by:

$$\mathcal{A} = 4\pi N_{mol} N_{res} \frac{e^{(-\pi\eta/2)} \left(\frac{q}{k}\right)^{i\eta} \Gamma(2 + i\eta)}{k^2 \Gamma(1 - i\eta)} \int_0^1 \frac{\left(\frac{1-t}{t}\right)^{i\eta}}{[1 - i(2t - 1)]^{1\eta+2}} dt. \quad (3)$$

We expect that $\frac{q}{k}$ is close to 1 near threshold and hence $\eta \approx Z_{eff}$. The Complex integrand is computed numerically [3]. Result for the $\eta = 2.8$ is equal to a complex number $0.3022i - 0.04153$. Finally, the probability of the nuclear fusion is calculated and our results as well as others are given in the full text.

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